DOCUMENT RESUME

ED 260 387 CS 008 132

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TITLE Effects of Text Display Variables on Reading Tasks: Computer Screen vs. Hard Copy. CDC Technical Report No. 3.
INSTITUTION Carnegie-Mellon Univ., Pittsburgh, PA. Communications Design Center.
REPORT NO CDC-TR-3
PUB DATE Mar 85
NOTE 15p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cognitive Processes; Comparative Analysis; *Computer Science; *Display Systems; Graduate Students; Higher Education; *Information Retrieval; Periodicals; Reading Processes; *Reading Research; *Recall (Psychology)
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ABSTRACT

Two studies were conducted to compare subjects' performance reading texts displayed on a computer terminal screen and on paper. In the first study, 10 graduate students read a 1,000-word article on knee injuries from "Science 83" magazine and were tested for recall of information on eight items. While subjects in the control condition (reading hard copy) were more accurate in spatial recall of text sequence, vertical spacing, and horizontal spacing, the results were statistically significant only in the category of vertical location. In the second study, 15 graduate students were timed for retrieval of information. Subjects read texts in three conditions: (1) hard copy (paper), (2) a standard CRT screen with text presented on 12 screens with a baud rate of 4800, and (3) a 19-inch diagonal screen with text presented in 5.5 screens. Results showed that subjects read significantly faster under conditions one (paper copy) and three (large screen) than under condition two (normal CRT.) (Author/HOD)

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ED260387

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Effects of Text Display Variables on Reading Tasks: Computer Screen vs. Hard Copy

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March 1985

CDC Technical Report Series

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March, 1985

Effects of Text Display Variables on Reading Tasks: Computer Screen vs. Hard Copy

Abstract: Two studies were conducted to compare subjects' performance reading texts displayed on a computer terminal screen and on a printed hard copy. Study 1 measured accuracy of spatial recall of information. While subjects in the control condition (reading hard copy) were more accurate in spatial recall of text sequence, vertical spacing, and horizontal spacing, the results were statistically significant only in the category of vertical location. In Study 2, subjects in one hard copy and two computer conditions were timed for retrieval of information. Results showed significant differences in performance between the control (hard copy) and computer condition 1, and between the two computer conditions. There was no significant difference between subjects' performance in the hard copy condition and in computer condition 2.

Although display of information on computer screens is increasing in both education and business and industry, questions about the essential differences between reading printed material and reading on a computer terminal have only been tentatively explored. Bork (1983) outlined a preliminary taxonomy of methods of screen display while noting both the importance and the scarcity of emperical studies of terminal display of information. Merrill's (1982) exploratory guidelines for screen format, paging, ease of use, interaction, and formative evaluation were based on anecdotal reports of users rather than experimental evidence. Sekey and Tietz (1982) conducted research using a novel single-line display of text not in common use, and Atkinson, in studying children reading using computers, did not specifically address the issue of text display. Muter, Latremouille, and Treuniet (1982) found little difference in comprehension between subjects reading from a television screen and those reading from a book, although subjects in the video condition read at a rate 28.5% slower. Gould and Grischkowsky (1984) found subjects read significantly faster and slightly more accurately on hardcopy than on screen. Wright and Lickorish (1983)

similarly found hard copy proofreading to be faster and more accurate. Interview data (Haas and Hayes, 1985) suggest that even experienced computer writers use hard copy printouts of their texts, especially for reading to revise and for proofreading.

Two related reading skills which might be affected by video screen display are recalling location of information (spatial recall) and retrieving information from a previously read text. These two studies were designed to explore whether--and to what degree--readers' performance in spatial recall and retrieval is constrained by computer display.

Experiment 1

Locating information in texts depends partly on spatial recall: remembering where (in the text and on the page) a given item of information occurred. In a study of spatial recall, Rothkopf (1971) found that subjects, reading from printed texts, showed significant incidental memory both within specific pages and within the text sequence Study 1 was designed to test whether reading on a computer screen constrains spatial recall.

Subjects: Ten students (six women and four men) in the Master's of Professional Writing and Master's of Arts Programs in the English department of Carnegie-Mellon University were randomly assigned to either the control (hard copy) or the experimental (terminal) condition. All subjects had had some computer experience and were familiar with the EMACS text-editing system. Subjects in the experimental condition read from a standard Bantam terminal with a 24 line by 80 character CRT display and a 4800 baud rate; they were given a brief review session on EMACS (Stallman, 1981) editing commands before being tested.

Materials: Subjects in all conditions read a 1000-word article on knee injuries from *Science '83* magazine. They were told to read normally, neither skimming nor memorizing facts. The texts used in the two conditions were made as similar as possible--identical line-length, page-length, and spacing--both to minimize interference and to facilitate scoring.

Method: Subjects were tested for recall of information of eight items; a full sentence was read to the subjects from the text and they were asked to recall: 1) text-sequence location and 2) within page location of specific words. Control group subjects used a notebook with blank pages, similar to the one from which they had read the original text, and they used a pen to indicate where they thought the information had occcurred in the text. Experimental groups subjects used a computer file the same length as the original file, but filled with blank spaces; they moved the cursor and typed in a number to indicate where the information had occurred.

> Sample Question: "Probably the most famous knees in football are those of former Jet quarterback Joe Namath." Put a small "2" where you remember seeing the words "Joe Namath."

Analysis: Each subject was given three scores for each of the eight questions:

1. Text-sequence score (page or screen number).

2. Vertical score (line or row number)

3. Horizontal score (character or column number)

Differences between given answers and correct answers were computed and tallied in each category for each subject. (See Table 1.) Variance was calculated between groups for each category. ANOVA tables are attached. (See Table 2.)

Results: In each category, subjects in the control condition scored better than subjects in the experimental condition. Differences in vertical location (line number) scores were significant at the $p < .05$ level; neither text-sequence location nor horizontal location differences were statistically significant.

Discussion: The results of this study suggest a difference between spatial recall of information presented on a terminal screen and on a hard copy. The difference in recall of vertical location was the one statistically significant difference. This result might have been expected if the experimental group subjects had read text from a scrolling screen, or if the amount of information presented on screen and page varied; but as the experimental text was identical in row number per page as the control group text, the result seems somewhat more conclusive. Given this difference, further studies might explore whether this is due to inherent differences in terminal screen reading and hard copy reading, or to subjects' greater experience with printed texts.

Experiment 2

Study 1 demonstrated that readers can locate specified words more accurately in the hard copy condition than in the computer screen condition. This result suggests that readers would find it easier to relocate information in a text to answer questions in the hard copy condition than in the computer condition. Study 2 attempts to verify this prediction. Subjects read texts in three conditions:

> --Condition1/Control: subjects read from a printed text, 3 1/2 pages long. The text was printed in Times-Roman 12 by a Xerox 9700 printer.
>
> --Condition 2: subjects read from a standard CRT screen (24 lines by 88 characters) and used control key commands to move from screen to screen. The text was presented on twelve screens with a baud rate of 4800. All subjects assigned to this condition were familiar with the text-editor and the terminal they used. Because the text editor contains "search" commands,--and because use of these commands might aid the subjects in the task--they were instructed in using these "search" commands, although only one subject had not

used them previously. This text-editor uses percentage indicators at the bottom of each screen to signal text length and location, and control-keys to move through the text.

--Condition 3: subjects read from a large-screen terminal and used a text-editor currently being developed at Carnegie-Mellon University by the Information Technology Center. This terminal has a 19-inch diagonal screen with multiple windows. The window in which the text was presented in this experiment was 50 lines by 94 chatacters, and the text was presented in five and on-half screens. The screen display contains multiple fonts and dark-on-white text display. The text-editor uses a side scroll-bar to graphically represent text length and location, and subjects used this scroll bar, a pointer, and a mouse to move through the text. See Table 3 for a summary of computer differences.

Subjects: Fifteen subjects, male and female undergreaduate and graduate students in Humanities and in Engineering, were assigned to a control (hard copy) condition and two computer conditions. All subjects had had some text-editing experience. Subjects in Condition 3 were familiarized with the new computer system in a brief training session and demonstrated mastery of devices and options before being presented with the task.

Materials: Subjects read a 1800-word self-help file for a bulletin-board feature on the computer system in use at Carnegie-Mellon University. The document contained tabled lists of commands as well as standard written text.

Method: Subjects were instructed to read the document as they normally would and that they would be asked questions (for which they could refer to the text) when they had finished reading. For the retrieval task, subjects were asked a series of questions, some of which were answered explicitly in the text, and others for which the answer must be inferred from information given in the text. They were told to go to the page or screen where the information--either explicit or implicit--was presented, to indicate verbally when they had found the information, and then to answer the question. They were instructed to locate the information even if they could answer the question without returning to the text. Six of the 12 questions required accessing information directly from the text, and six required inferencing. Responses were timed and answers were used to check that subjects were returning to specific places in the text. Incorrect responses were less than one per subject and were distributed over questions and conditions.

Results: The mean response times (presented in Table 4) were 13.0 seconds for Condition 1, 32.7 seconds for Condition 2, and 15.9 seconds for Condition 3. One subject in Condition 2 and one subject in Condition 3 gave up before finding the answer to one question. For these subjects, eleven response times were averaged for the mean score. Three-way analysis of variance (presented in Table 5) shows a signficant difference ($p < .01$) between conditions, and Newman-Keuls analysis (presented in Table 6) shows significant differences ($p < .01$) between conditions 1 and 2, and between conditions 2 and 3. The difference between conditions 1 and 3 (hard copy and advanced computer system), however, was not significant.

Subject performance with the advanced computer system approaches that of subjects using hard copy. Determining what kinds of differences remain between these two conditions will require further research.

Discussion: These result indicate that reading *is* constrained by the computer, especially a standard text-editor and CRT display. Some of this constraint is removed with a more sophisticated computer system. The differences might be the result of any number of display variables; these variables are summarized in Table 3. While these results indicate that newer text-editors and high-resolution, bit-mapped displays ease some constraints, several questions remain. First, it is not clear from these results which variables cause the difference between the two computer conditions. Further tests could isolate the text-editor variables from the screen display variables to determine which is the most signficant. The machine response speed could also be isolated and controlled to determine its impact on the task. Second, because these subjects were good readers and experienced computer users, we do not know if less experienced users and/or poor readers would also be aided by advances in design. Third, retrieval of information is only one of many skills needed by good readers and writers. How the computer effects other reading and writing skills remains to be determined.

General Discussion

As Study 1 reports, subjects presented with information on a standard terminal display were less accurate in a spatial recall task. In Study 2, there were significant differences between time needed to retrieve information when texts were presented on a hard copy and on a standard terminal. Differences were minimized in a second compuler condition, using a more sophisticated screen dispplay and text-editor.

Spatial recall and retrieval of information from texts are necessary skills for writers as well as readers. As computers become increasingly available for educational use in schools and for communication in business, the machine's effects on readers and writers should continue to be explored. Among the research questions worth pursuing are:

*How do display variables, machine speed, and differences in text-editors contribute to reading constraints on text editors?

*Does increased experience with computer lessen the constraints on reading and writing?

*Does the computer effect poor readers and writers differently than it does good readers and writers?

*What strategies do good readers and writers use to overcome the constraints of computer reading and writing?

*Does the computer constrain performance on other reading and writing tasks? How?

Table 1

Mean Scores for Spatial Recall*

Group 1 -- Hard Copy Reading

Subj.	Text Sequence	Vertical	Horizontal
A	8	29	113
B	13	28	69
C	15	32	140
D	10	30	63
E	13	31	75
Total	59	150	460

Group 2 -- Terminal Reading

Subj.	Text Sequence	Vertical	Horizontal
AA	11	31	80
BB	11	46	97
CC	13	64	120
DD	16	39	181
EE	17	45	110
Total	68	225	588

* Mean scores are for eight questions. A "perfect" score would be "0" in each category.

Table 2

Analysis of Variance For Spatial Recall Experiment

Text-Sequence Location (page or screen)

Source	df	SS	MS	f	
Between-groups	1	8.1	8.1	1.045	NS
Within-groups	8	62	7.5		
Total	9	70.1			

Vertical Location (line)

Source	df	SS	MS	f	
Between-groups	1	562.5	562.5	7.44	<.05
Within-groups	8	604	75.5		
Total	9	1166.5			

Horizontal Location (Column)

Source	df	SS	MS	f	
Between-groups	1	1638.8	1638.8	1.269	NS
Within-groups	8	10325.2	1290.65		
Total	9	11964			

Table 3

Summary of Display Variables

	Condition 1	Condition 2 Computer	Condition 3 Computer
screen or page size:			
inches:	8 1/2 x 11	9 1/2 x 61/2	9 1/2 x 10 1/2
characters:	58 lines x 72 characters	24 lines x 88 characters	50 lines x 90 characters
number of screens or page to present text:	3 1/2	12	5 1/2
screen and type:	black-on-white	CRT display; white-on-black	high resolution bit-mapped display; black-on-white
fonts:	non-variable	non-variable	variable
representation of text size and location	-----	percentages at bottom of screen	scroll-bar
commands for changing screen	-----	control keys	mouse and pointer
speed	-----	4800	16 kilo-baud

Table 4

Mean Times for Information Retrieval

	Condition		
	#1 Hard Copy	#2 Standard Computer	#3 Advanced Computer
	11.08	36.18	19.58
	11.50	31.08	15.90
	19.25	37.75	16.83
	13.75	31.92	17.91
	9.42	26.75	9.75
Mean:	13	32.7	15.9

Table 5

Three-way Analysis of Variance for
Information Retrieval Experiment

Source	df	SS	MS	f	
Between-groups	2	1131.27	565.63	35.57	<.01
Within-groups	12	190.81	15.90		
Total	14				

Table 6

Newman-Keuls Test of Significance for
Information Retrieval Experiment

	hard copy	advanced computer	standard computer
hard copy	***	1.63*	11.05**
advanced computer		***	9.42**
standard computer			***

*not significant

**significant at .01 level

References

Atkinson, R. (1974). Teaching children to read using a computer. *American Psychologist 29*, 169-78.

Bork, A. (1983). A preliminary taxonomy of ways of displaying text on screens. *Information Design Journal, 3*, 206-214.

Gould, J., and Grischkowsky, N. (1984). Doing the same work with hard-copy and with CRT terminals. *Human Factors 26*(3), 323-337.

Haas, C. and Hayes, J. (1985). Writing with the machine: observational and experimental data. In progress.

Merrill, P. (1982). Displaying text on microcomputers. In David J. Jonassen, ed., *The Technology of Text: Principles for Structuring, Designing, and Displaying Text*. Englewood Cliffs: Education Technology Publications. 401-414.

Muter, P., Latremouille, S., Treuniet, W., and Beam, P. Extended reading of continuous text on television screens. *Human Factors, 24*(5), 501-08.

Rothkopf, E. Z. (1971). Incidental memory for location of information in text. *Journal of Verbal Learning and Verbal Behavior 10*, 608-613.

Sekey, A. and Tietz, J. (1982). Text display by saccadic scrolling. *Visible Language 16*, 62-77.

Stallman, R. M. (1981). *EMACS: The Extensible, Customizable Self-Documenting Display Editor*. ACS SIGPLAN SIGOA SYMPOSIUM on Text Manipulation.

Wright, P. and Lickorish, A. (1983). Proof-reading texts on screen and paper. *Behavior and Information Technology, 2*(3), 227-235.